

General Morphological Analysis: Modelling, Forecasting, Innovation

Editors' Introduction

Tom Ritchey & Tomasz Arciszewski

1. Background

The term *morphology* (from the Greek μορφή, *morphé* = form) is used in science in a number of different contexts and on a number of different conceptual levels. On the most general level, it refers to nothing less than a philosophy of science, or at least what Lakatos (1968) calls a basic scientific research program, i.e. a set of theoretical (or ontological) assumptions and methodological ground rules upon which to approach scientific enquiry in general. Although the term “morphology” was only coined at the end of the 1700’s, the scientific tradition it represents dates back to antiquity (see below).

On another level, we find morphology and *morphological analysis* denoting a general methodological approach used in a wide range of scientific disciplines concerning the study of *structural inter-relationships within the context of a developing systemic whole*. For example, geomorphology is the study of landforms and the processes that shape them. Urban morphology is the study of human settlements and the process of their formation. In linguistics, morphological analysis is the branch of grammar that studies the structure of word forms and their development over time.

However, it is in the field of biology – for which the term was originally coined by Goethe – that it developed into a method for the study of organic form in general, both in its structural and developmental (morphogenetic) sense (Russell, 1916; Thompson, 1917). More recently, the sub-discipline of *theoretical morphology* has been able to work with multivariate analysis of organic form based on the *morphospace* concept (McGhee, 1999).

Finally, on a purely technical-methodological level, *morphological analysis* (which in this context should actually be termed *morphological analysis and synthesis*) refers to a basic modelling method, on a par with other modelling methods such as System Dynamics Modelling (SDM) and Bayesian Networks (BN). Although morphological modelling is essentially “qualitative” (i.e. non-quantified and non-causal), it relies on the same principles of construction, and the same iterative process of analysis and synthesis, as all other scientific modelling methods

This Special Issue of the *Journal of Technological Forecasting and Social Change* is not about Morphology as a philosophy of science, or of how morphological analysis is applied to any specific scientific discipline (although both of these themes remain fluttering in the background). It is primarily concerned with this third, methodological context, i.e. morphological analysis as a *general method for conceptual modelling* and, as such, a procedure which facilitates discovery and invention. However, before proceeding it is instructive to take a look at some of the milestones in the history of what we now call *morphological modelling*.

2. Examples in the history of morphological modeling

As far as its ancient roots go, one of the earliest, explicit examples of a conceptual modeling procedure is that of Plato's *dialectic method of divisions and collections* (*diairesis and sunairesis*, usually simply referred to as the "method of divisions", see Philip, 1966). This was put forward around 350 BC in the dialogues *Phaedrus*, the *Sophist* and the *Statesman*. Plato has Socrates alluding to "a certain pair of procedures":

"The first is that in which we bring a dispersed plurality under a single form, seeing it all together – the purpose being to define each thing and thus make clear whatever may be chosen as the topic of exposition." ... "The reverse [of this is] to be able to cut up each kind according to its species, along its natural joints, and to try not to splinter any part, as a bad butcher might do..." (Phaedrus, 265d)

Just as one must not *divide* arbitrarily, like a "bad butcher", one must also not *collect* indiscriminately, but "distinguish in what ways the several kinds can and cannot combine" (Sophist, 253d-e). Plato gives the analogy of how letters combine to form words, but that not all combinations of letters can be conjoined meaningfully. The two procedures are complementary; one can either begin by collecting lower-order concepts or dividing higher order concepts, depending on the problem to be treated. The procedures are also iterative and can proceed in steps "upwards" or "downwards" until one has reached a satisfactory understanding of the topic of discussion. (Cf. Ionescu, 2012; Mainwald, 2016).

Although Plato never fully systemized this process – that had to wait for the later neo-Platonic philosophers – these procedures are a tolerable description of the analysis-synthesis cycles involved both in scientific modelling in general (Ritchey, 1991; Gill, 2006; El Murr, 2006) and in engineering design (Norris, 1963; Arciszewski, 1984; Codinhoto, *et. al.*, 2006).

Fast forward fifteen centuries: the Majorcan monk Ramon Llull (1232-1315), building upon earlier Neo-Platonic accounts of *diairesis*, developed what would later be called the Art of Combinations (*Ars Combinatoria*) as a way of dealing with all of the possible interconnections between analysed concepts. Among other things, he developed a conceptual calculator in the form of a circular slide rule that allowed for the display of all the combinations between the components of different concepts. Although principally concerned with theological concepts (he wanted to promote Christian theology within a "rational" framework), Llull seems to have been the first to systematically develop what we today is called a *morphospace* and the combinatoric process embodied in a *cross-consistency matrix* (Llull, 1313; Bonner, 2007).

Three hundred years later, Llull's pioneering work made a great impression on the young Gottfried Wilhelm Leibniz (1646-1716). It inspired him, at the age of 20, to found the mathematical discipline of *combinatorics* (a term he coined). In his *Dissertation de ars combinatoria* (1666), he presented a fully systemised version of morphological analysis (i.e. "analysis and synthesis by combinations") and gave twelve example applications, including an analysis of contemporary contract law and a means of discovering and demonstrating the full set of possible syllogistic forms.

In “On Universal Synthesis and Analysis, or the Art of Discovery and Judgment” (1679), Leibniz established the modern notion of analysis and synthesis as reciprocal procedures both for structuring and defining a given area of inquiry, and for facilitating discovery and invention within that area. Indeed Couturat (1902), in his seminal work on Leibniz’ philosophy of science, sums up this methodology in a way that essentially defines modern morphology as a conceptual modelling procedure:

“In sum, analysis consists of decomposing concepts into their simple elements by means of definition; and synthesis consists of reconstituting concepts starting from these elements using the art of combinations.” (Couturat, 1902, Chapter 6, p 4.)

However, this “universal” conceptual modelling method was for Leibniz only part of a much larger program. While the English-Scottish-French enlightenment was making great strides in “mechanising” the philosophy of natural science, Leibniz thought that they were throwing the preverbal baby out with the bathwater. He took Renaissance neo-platonic science, secularised it from all occult qualities and formulated the epistemological-ontological ground-rules for an “organic” approach to scientific enquiry (*Discourse on Metaphysics*, 1686; *Monadology*, 1714). This so-called “relational” or “holographic” approach (Bohm, 1980; Rosen, 1985; Bortoft, 1996; Smolin, 2013) concentrates not only on how parts of a system interact with one another (i.e. mechanically), but also on how the parts of a system relate to and interact *reciprocally* to the developing system as a whole (i.e. mereologically).

It was upon this scientific program that Johann von Goethe (1749-1832) was inspired to develop *morphology* both as a holistic philosophy of science and as a method for studying the life sciences (Goethe, 1995). In this approach, living systems are treated as open-ended and emergent; the *process of structural development* is fundamental, not the structure itself; and *functional teleology* (as an *architectonic principle*, not as supernatural design) is applied as a necessary complement to mechanical or efficient causes (Lenior (1982) termed this the “teleo-mechanical” approach; Rosen (1985) called it “anticipatory systems”). Indeed, Goethe developed “morphology” with the expressed purpose of methodologically distancing the life sciences from the “ontological misuse” of a purely mechanical natural philosophy in biology (Hegge, 1987; Lenior, 1987).

According to Fritz Zwicky himself, it is principally from Goethe that he gained inspiration to develop his “morphological method of analysis and construction” (Rudnicki, 2005). He also mentions Ramon Llull, but it is indeed odd that he totally “misses” Leibniz’s earlier development of the method. This is especially interesting in that Zwicky’s doctoral thesis advisor, Herman Wyle, was thoroughly steeped in Leibniz’s physics and metaphysics. But a discussion of this issue will have to wait for a more suitable occasion.

3. Fritz Zwicky

“Attention has been called to the fact that the term morphology has long been used in many fields of science to designate research on structural interrelations – for instance in anatomy, geology, botany and biology. ... I have proposed to generalize and

systematize the concept of morphological research and include not only the study of the shapes of geometrical, geological, biological, and generally material structures, but also to study the more abstract structural interrelations among phenomena, concepts, and ideas, whatever their character might be.” (Zwicky, 1969, p. 34)

Fritz Zwicky (1898 – 1974), Professor of Astrophysics at the California Institute of Technology (Caltech), developed the “morphological approach” as a conceptual (non-quantified) modelling method which, like all scientific modelling, is based on an iterative process involving cycles of *analysis* and *synthesis*. (The theoretical basis and methodological description of this process is given in Ritchey (this issue) – and we need not go into further detail here.)

Zwicky was born in Bulgaria (1898) to a Swiss father and a Czech mother. At the age of six, he was sent to his ancestral canton of Glarus, Switzerland, in the middle of the Schwyzer Alps (Zwicky was a life-long mountain climber). In 1914 he moved to Zurich where he studied engineering, mathematics and experimental physics at the Swiss Federal Institute of Technology (ETH).

In 1925 he moved to the United States to work at the California Institute of Technology (Caltech) in Pasadena. From this point onward, until his death in 1974, Zwicky was essentially based at Caltech, but considered himself a “free world citizen” with a totally global perspective (see Stockli & Müller, 2012, for a biography of Zwicky). In addition to being professor of astrophysics at Caltech and the Mount Wilson Observatory, he was also research director at Aerojet Engineering Corporation for nearly twenty years. In this later position he worked as an inventor, producing some 50 patents, mostly related to the development of jet and rocket propulsion systems. At the end of World War II, he was appointed head the U.S. research team that travelled to Germany and Japan to evaluate *inter alia* the development and use of jet aircraft during the war. Because of this, and his subsequent work at Aerojet, he was considered by some of his contemporaries as being “the father of the modern jet engine.”

Fritz Zwicky is not a household name in science today. He was not a superstar of the likes of Albert Einstein, Ervin Schrödinger or Robert Oppenheimer. Yet his influence was significant; far more than his present-day lack of recognition would suggest (and his recognition is presently growing, cf. Ritchey, 2012b). He was one of the most innovative scientists of his time, combining “high-flyer” theoretical studies with practical, inventive engineering design. He was also a great humanitarian, engaged in a number of charitable activities including years of personal toil to help rebuild scientific libraries in Europe destroyed during the war and participating in the Pestalozzi Foundation's program to establish war orphan villages.

Zwicky is primarily known for his work in astrophysics and especially his comprehensive galaxy surveys. He coined the term supernova and was the first to hypothesise the existence of neutron stars (1934). He was also the first to discover evidence for *dark matter* (Zwicky, 1933), which is at the very forefront of astrophysics today. He thrived on investigating and theorizing about extreme phenomena and *boundary conditions*. This led him to develop methods for systematically investigating multi-dimensional problem complexes, which eventually became his “morphological approach”.

Zwicky was well aware that the “morphological method” had a long history in science:

“Morphological thinking, without having been strictly formalised (sic), has actually been applied by many scientists in the past, particularly by mathematicians. For instance, the introduction of generalised coordinates and the formulations of general laws of classical mechanics by Lagrange is a case in point. ... In physics, biology, botany, geology, and other disciplines the morphological method has played an important role. In *sociology and statecraft*, where prejudices, conventions and narrow ideologies interfere, the method is more difficult of application *although is it precisely in these fields where it could be most beneficial.*” (Zwicky, 1948, p. 121f, emphasis added)

Thus, in 1948 when he was invited to deliver the prestigious Oxford University Halley Lecture, he decided not to talk about his discoveries in astronomy or astrophysics, but about Morphological Analysis instead – i.e. *the method as such*. He believed that this method would become the key to many discoveries and inventions, and hoped – as Leibniz and Goethe before him – that it would contribute to bridging narrow political and ideological interests. He wrote: “*I feel that I have finally found the philosopher’s stone*” (Greenstein & Wilson, 1974). For Zwicky, morphology and humanism went hand in hand.

4. GMA and the issue of “wicked problems”

“Morphological thinking will not be popular among dictators.” (Fritz Zwicky, Morphological Astronomy, 1948, p 123.)

The areas of application that Zwicky refers to as “sociology and statecraft” differ fundamentally from those of natural science and engineering design *as such*. The main difference is that they are essentially *policy driven problems* concerning norms, values and motivations. This is the type of problem that Zwicky addressed in an article concerning the “smog problem” in Los Angeles in the late 1950’s. There he states that the morphological approach is especially applicable to such complex policy driven problems that require “... an integrated view which relates [technical,] political, psychological and ethical factors ...[which] ... add up to a complex task which is beyond the power of ordinary scientific, technical and managerial experts.” (Zwicky, 1960).

A few years later Horst Rittel, the design theorist at the University of Berkeley in California, coined the term “wicked problems” to refer to such complex, policy driven issues (Churchman, 1967; Rittel, 1972). In 1973, Rittel and his colleague Melvin Webber introduced this concept to a broader audience with their article for Policy Sciences, “Dilemmas in a General Theory of Planning” (Rittel & Webber, 1973). Both the article and the concept are now famous, at least within the design community (see. e.g. Buchanan, 1992), with the “soft side” of Operational Research/Management Science, and with most morphologists.

Since morphological analyses applied to policy driven issues essentially deal with “wicked problems”, and since many of the articles presented in this issue either explicitly or implicitly address such problems, a short summary of the concept is in order (although we suspect that many of the readers of TF&SC are already acquainted with the concept).

Wicked problems (WPs) are typically ill-defined, ambiguous and associated with strong moral, political and professional issues. They concern competing stakeholder interests, rival ideologies and any number of subjective “people problems”. Most importantly, wicked problems *won't keep still*: they are open-ended sets of complex, interacting issues continuously evolving in a dynamic social context. Often, new forms of wicked problems emerge *as a result* of trying to understand and “solve” one of them (Conklin, 2006; Ritchey, 2011; 2013).

Of course, wicked problems are nothing new; they are as old as human society. But they were raised to a new level of consciousness – and given a catchy name – in the context of post-war urban society of the 1950's and 60's. Rittel & Webber put forward ten example “criteria” for identifying WPs. We need not go through all of these. For our purposes, we present those aspects of WPs to which general morphological analysis has been found to be especially applicable. (GMA is, of course, not a cure-all and there are other aspects of WP's that would seem to defeat any “formal” method of attack.)

1. There is no definite formulation of and no definite “solution” to a wicked problem

"The information needed to *understand* the problem depends upon one's idea for *solving* it. This is to say: in order to *describe* a wicked problem in sufficient detail, one has to develop an exhaustive inventory for all the conceivable *solutions* ahead of time."

GMA's position: A morphological model represents both the total problem space and as many of the potential solutions to the given problem complex as possible. This goes a long way in satisfying this seemingly incredible criterion. With dedicated computer support, the solution space can be treated as an input-output model, with which stakeholders and subject specialists can manipulate in order to better understand the problem space, the alternative solutions available and the possible consequences (including those unintended) of alternative decisions/actions.

2. Solutions to wicked problems are not true-or-false, but better or worse.

The criteria for judging the validity of a "solution" to a wicked problem are strongly stakeholder dependent. However, the judgments of different stakeholders ... "are likely to differ widely to accord with their group or personal interests, their special value-sets, and their ideological predilections." Different stakeholders see different "solutions" as simply better or worse.

GMA's position: The *group process* of developing a morphological model in a facilitated workshop setting is as important as the end-product - i.e. the model itself. As many stakeholders as possible should be engaged in the work, in order to create a common terminology, common problem concept and common modelling framework. Principal stakeholders and subject specialists should therefore be brought together in a series of workshops to collectively 1) structure as much of the problem space as possible, 2) synthesize solution spaces, 3) explore multiple solutions on the basis of different drivers and interests and 4) analyse stakeholder positions. The various stakeholders do not have to agree on a single, common solution, but are encouraged to understand each other's positions and contexts.

3. Every wicked problem is essentially unique, and must be addressed as such.

"There are no *classes* of wicked problems in the sense that the principles of solution can be developed to fit *all* members of that class." ...Also, ..."Part of the art of dealing with wicked problems is *the art of not knowing too early which type of solution to apply*." (Emphasis added.)

GMA's position: In the GMA facilitation process this is called "remaining in the mess", i.e. keeping one's options open long enough to explore as many relationships in the problem topology as possible, before starting to formulate solutions. This can be a frustrating process for inveterate "problem solvers", but is an absolutely necessary procedure when modelling wicked problems.

4. Every wicked problem can be considered to be a symptom of another [wicked] problem.

Many internal aspects of a wicked problem can be considered to be symptoms of other internal aspects of the same problem. A good deal of mutual and circular causality is involved, and the problem has many causal levels to consider. Complex judgements are required even in order to determine an appropriate *level of abstraction* needed to define the problem.

GMA's position: With a morphological model one can treat any particular parameter as the starting point, driver or "independent" variable. This allows one to change perspectives and treat different issues as both causes and effects. Everything is connected, which is what both wicked problems and morphological analysis are all about.

5. GMA's main areas of application

Zwicky applied GMA to three broad fields of study: firstly within natural science, in this case to astronomy and astrophysics (Zwicky, 1948); secondly to engineering design (Zwicky & Wilson, 1967, Zwicky, 1969), especially jet and rocket propulsion systems; and thirdly to social and organisation systems, including legal and ethical issues – i.e. complex, (wicked) policy driven problems (Zwicky & Wilson, 1967).

In a survey of the literature from 1950-2015 (Álvarez & Ritchey, 2015) it was found that almost all of the applications of *general* morphological analysis (i.e. excluding traditional discipline-specific forms such as geomorphology, linguistic morphological analysis, etc) could be divided into four broad (admittedly not water-tight) categories. These are:

- Engineering design, architecture and general design theory
- Scenario development, technological forecasting and futures studies in general
- Policy analysis, operational research/management science (OR/MS) and social/cultural modelling (SOCUMOD) in general
- Creativity, innovation and knowledge management

These, of course, can be broken down into any number of sub-categories, but this tends to make things even fuzzier. Here we summarise from the cited categories:

5.1 Engineering design, architecture and general design theory

GMA is highly applicable for conceptual design in engineering and architecture, given the large number of diverse variables generally involved and the need to structure and collate these. Indeed, engineering design was one of the main applications for GMA from its beginnings (e.g. Norris, 1963; Arciszewski 1984, 2016; Álvarez, 2014). With far more advanced IT techniques now available, the application of GMA within this area is becoming more widespread. Represented in this issue are Tomasz Arciszewski's "Morphological Analysis in Inventive Engineering" and Wim Zeiler's "Morphology in conceptual building design".

5.2 Technological forecasting, scenario development and futures studies

Using GMA for scenario development and futures projections was one of the early spinoffs from Zwicky's work. This is because of the many non-quantified social, political and ideological variables that need to be taken into account, and the inherent uncertainties involved. Also, a number of often cited, early works from the late 1960's describe how GMA began to be applied as a method for technology foresight. One of the pioneers in this area was Erich Jantsch, with his book *Technological forecasting in perspective* (1967). Jantsch started out in astrophysics and thus had early knowledge of Zwicky's work. Today, modern GMA is firmly established as one of the basic methods employed in technology foresight studies. Articles in this issue concerning scenario development are Iver Johansen's "Scenario Modelling with Morphological Analysis" and Joseph Voros' "On a Morphology of Contact Scenario Space".

5.3 Policy analysis, operational research/management science (OR/MS)

Although GMA started off as problem structuring method in engineering design and as a technique for developing scenarios, it eventually became clear that it was excellent method for structuring policy spaces and strategy alternatives, and for organisational planning. All of these are natural complements to developing scenario spaces and have been used extensively for government authorities and NGOs. Of particular interest have been studies of societal security and safety. For various reasons, defence and security analysis is one of the areas that adopted GMA at a relatively early stage. Applications in business management and the commercial sector have not developed as quickly as within the public sector for reasons concerning institutional goals and time horizons. Represented in this issue are Guy Duczynski's "Investigating Traffic Congestion: Targeting Technological and Social Interdependencies through General Morphological Analysis"; Peter Haydo's "From Morphological Analysis to Optimizing Complex Industrial Operation Scenarios", and Maria de Fátima Teles & Jorge Freire de Sousa's "Linking Fields with GMA: Sustainability, Companies, People and Operational Research"

5.4 Creativity, innovation, knowledge management and modelling theory

Morphological analysis is featured, or at least mentioned, in most books and articles concerned with methods and techniques for innovation and creative problem solving. In this sense, there are literally thousands of articles to choose from. Also, the technical side of GMA has been addressed in the areas of decision theory and modelling theory in general. Repre-

sented in this issue are Tom Ritchey's "General Morphological Analysis as a basic modelling method" and Marin Zec & Florian Matthes' "Web-based Software-Support for Collaborative Morphological Analysis in Real-Time".

As a supplement, under "From our perspective", Asunción Álvarez and Pablo Toja present "An Informal Survey on the Application of Morphological Analysis in the Private Sector"

Finally, as co-editors of this Special Issue, we wish to thank the authors for their excellent contributions as well as the editors of the *Journal of Technological Forecasting and Social Change* for allowing us to present this fascinating, still-developing method of conceptual modelling to its readers.

Tom Ritchey & Thomaz Arciszewski

6. References

Álvarez, A., 2014. The Norris Brothers morphological approach to engineering design. *Acta Morphologica Generalis*, 4(1).

Álvarez, A. & Ritchey, T., 2015. Applications of General Morphological Analysis: From Engineering Design to Policy Analysis. *Acta Morphologica Generalis*, 4(1).

Amrine, F., Zucker, F. & Wheeler, H., 1987. *Goethe and the sciences: a reappraisal, Boston studies in the philosophy of science*,. Dordrecht: D. Reidel Publishing Company.

Arciszewski, T., 1984. Design of Joints in Steel Space Structures. *Journal of Space Structures*, pp. 695-700.

Arciszewski, T., 1987. Mathematical modelling of morphological analysis. *Mathematical Modelling*, Volym 8.

Arciszewski, T., 2016. *Inventive Engineering*. New York: CRC Press.

Bohm, D., 1980. *Wholeness and the Implicit Order*. London: Routledge.

Bonner, A., 2007. *The Art and Logic of Ramon Llull - A User's Guide*. Leiden: Brill.

Bortoft, H., 1996. *The Wholeness of Nature: Goethe's Way of Science*. Edinburgh: Floris Books.

Churchman, W., 1967. Introduction: Wicked Problems. *Management Sciences*, 14(4).

Codinhoto, R., Koskela, L., Tzortzopoulos, P. & Kagioglou, M., 2006. How Analysis and Synthesis Have Been Understood in Design. *Proceedings IGLC-14*.

Conklin, J., 2006. *Dialogue mapping : building shared understanding of wicked problems*. Chichester: Wiley Publishing.

Couturat, L., 1902. *The Logic of Leibniz (Translated by Donald Rutherford and Timothy Monroe, 1997-2003)*. [Online] Available at: <http://web.archive.org/web/20030308235650/http://philosophy2.ucsd.edu/~rutherford/Leibniz/contents.htm> [Last assessed 2-9-2016].

El Murr, D., 2006. Paragim and diairesis. *PLATO 6* (Online at: <https://gramata.univ-paris1.fr/Plato/article63.html?lang=en>, last accessed: 2016-11-29).

Gill, M. (2006) Models in Plato's Sophist and Statesman. *Plato*, Volym 6.

Goethe, J. (1995) *Scientific Studies, Goethe: The Collected Works*, Miller, D., (ed.), (12). Princeton: Princeton University Press.

Greenstein, J. & Wilson, A., 1974. Remembering Zwicky. *Engineering and Science*.

Hegge, H., 1987. Theory of Science in the Light of Goethe's Science of Nature. in Amrine, et. al. (1987).

Ionescu, C., 2012. Recollectiion and the Methos of Collection and Division in the Phaedrus. *Journal of Philosophical Research*, Volym 37.

Jantsch, E. (1967) "Technological Forecasting in Perspective", OECD, Paris.

Lakatos, I., 1968. Criticism and the Methodology of Scientific Research Programmes. *Proceedings of the Aristotelian Society*, Volym 69, p. 149–186.

Leibniz, G., 1666. De Arte Combinatoria (Dissertation on the Art of Combinations), in Leibniz (1956).

Leibniz, G., 1679. On Universal Synthesis and Analysis, or the Art of Discovery and Judgment. i: L. Loemker, red. *Philosophical Papers and Letters*. Chicago: University of Chicago Press.

Leibniz, G., 1686. Discourse on Metaphysics, in Leibniz (1956).. i: u.o.:u.n.

Leibniz, G., 1711. Monadology, in Recher (1991).. i: u.o.:u.n.

Leibniz, G., 1956. Philosophical Papers and Letters, Edited by Leroy E. Loemke. Chicago: University of Chicago Press.

Lenoir, T., 1982. *The Strategy of Life*. Dordrecht: Reidel Publishing Company.

Lenoir, T., 1987. The Eternal Laws of Form: Morphotypes and the Conditions of Existence in Goethe's Biological Thought. in Amrine, et. al. (1987).

Llull, R., 1313. *Ars Brevis*. [Online]
Available at: <http://lullianarts.narpan.net/ArsBrevis.pdf> (Last accessed 2016-11-24).

McGhee, G., 1998. *Theoretical Morphology – The Concept and its Applications*. New York: Columbia University Press.

Meinwald, C., 2016. *Plato*. London: Routledge.

Norris, K., 1963. *The Morphological Approach to Engineering Design*. New York, Macmillan.

Philip, J. A., 1966. "Platonic Diairesis". *Transactions and Proceedings of the American Philological Association*, Volym 97, pp. 335-358.

Ritchey, T., 1991. Analysis and Synthesis - On Scientific Method based on a Study by Bernhard Riemann. *Systems Research*, 8(4).

- Ritchey, T., 2011. *Wicked Problems - Social Messes: Decision Support Modelling with Morphological Analysis*. Berlin: Springer.
- Ritchey, T., 2012a. Outline for a Morphology of Modelling Methods: Contribution to a General Theory of Modelling. *Acta Morphologica Generalis*, 1(1).
- Ritchey, T. (2012b). BOOK REVIEW: "Fritz Zwicky: An Extraordinary Astrophysicist". *Acta Morphologica Generalis*, 1(3).
- Ritchey, T., 2013. Wicked Problems - Modellinmg Social Messes with Morphological Analysis. *Acta Morphologica Generalis*, 2(1).
- Rittel, H., 1972. On the planning Crisis. *Bedriftsökomomin*, Volym 6.
- Rittel, H. & Webber, M., 1973. Dilemmas in a General Theory of Planning. *Policy Sciences*, 4.
- Rosen, R. (1985) Anticipatory Systems: Philosophical, Mathematical and Methodological Foundations, Pergamon Press.
- Rudnicki, K., 2005. Philosophical foundations of Zwicky's morphological approach in science. i: P. Flin & H. W. Duerbeck, red. *Morphological Cosmology*. Berlin: Springer.
- Russell, E. S., [1916] 1982. *Form and Function: A Contribution to the History of Animal Morphology*. Chicago: Chicago University Press.
- Smolin, L., 2013. *Time Reborn*. London: Allen Lane.
- Ströckli, A. & Müller, R., 2011. *Fritz Zwicky: An Extraordinary Astrophysicist*. Cambridge: Cambridge Scientific Publishers.
- Thompson, D., 1917. *On Growth and Form*. Cambridge: Cambridge University Press.
- Zwicky, F. (1933) *Helv. Phys. Acta*, 6, 110.
- Zwicky, F., 1948. Morphological Astronomy. *The Observatory*, 68(845).
- Zwicky, f. (1960) "A morphologist ponders the smog problem", *Engineering and Science*, 24 (2) pp. 22-26
- Zwicky, F., 1969. *Discovery, Invention, Research through the Morphological Approach*. Toranto: MacMillan.
- Zwicky, F. & Wilson, A. red., 1967. *New Methods of Thought and Procedure*. Berlin: Springer.